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Koike

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(54) **WIRELESS TAG COMMUNICATION DEVICE AND SHEET PROCESSING APPARATUS**

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(51) **Int. Cl.**

G06K 7/10 (2006.01)
G06K 19/077 (2006.01)
H04N 1/024 (2006.01)

(52) **U.S. Cl.**

CPC ***G06K 7/10435*** (2013.01); ***G06K 7/10316*** (2013.01); ***G06K 7/10356*** (2013.01);
(Continued)

(58) **Field of Classification Search**

CPC G06K 7/10435; G06K 7/10316; G06K 7/10356; G06K 7/10366; G06K 19/07773;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,187,339 B2 * 3/2007 Mori H01Q 9/0442 343/768
7,327,265 B2 2/2008 Tsujimura et al.
(Continued)

FOREIGN PATENT DOCUMENTS

JP 2005-311994 A 11/2005

OTHER PUBLICATIONS

Extended European Search Report dated Mar. 17, 2022 in corresponding European Patent Application No. 21180807.6, 9 pages.

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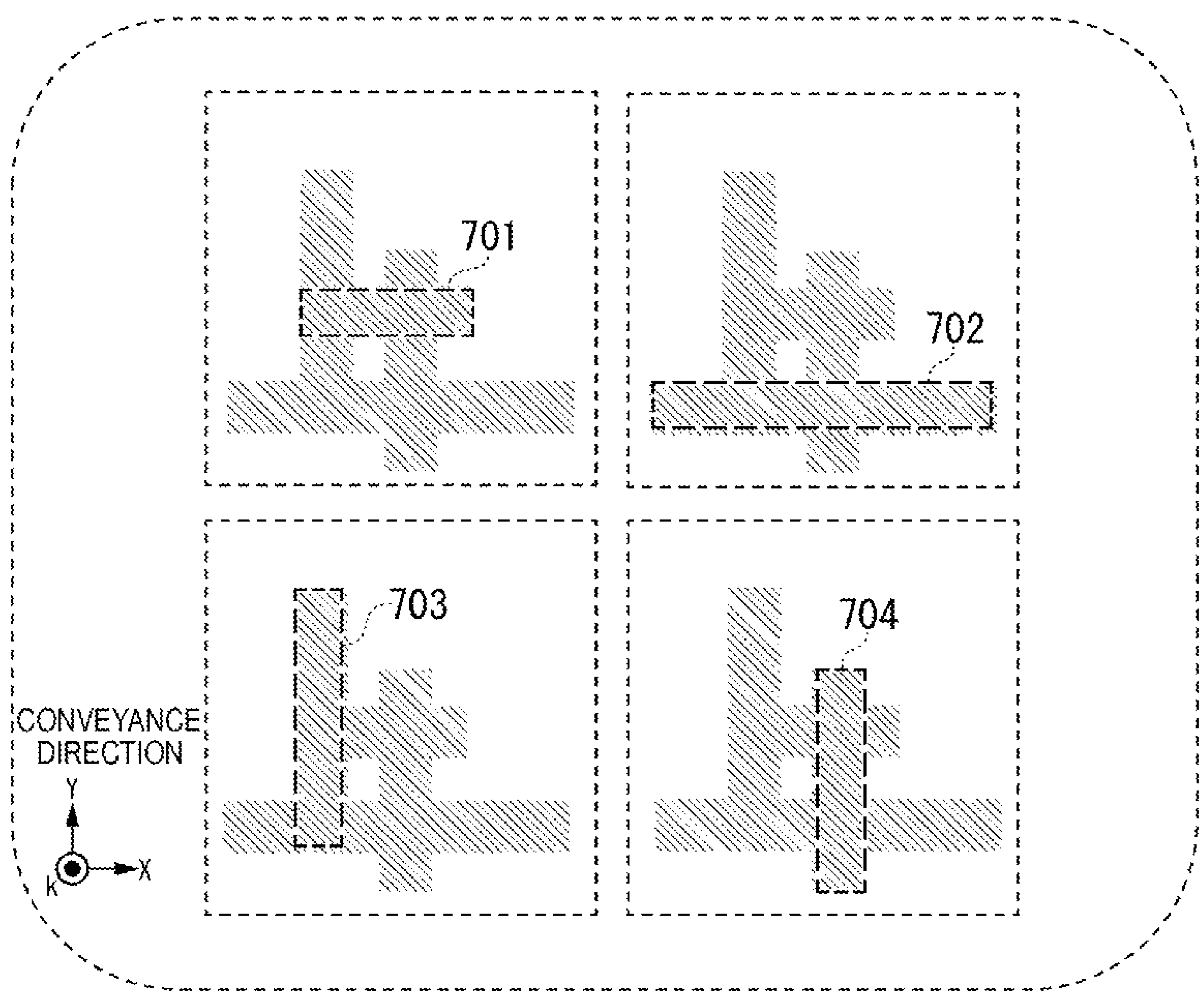
(57) **ABSTRACT**

A wireless tag communication device for communicating with a wireless tag conveyed by a conveyance mechanism, includes radiation regions from which a radio wave is emitted. The radiation regions include a first region extending along a first direction crossing a conveyance direction of the tag and having a first length in the first direction, a second region extending along the first direction and having a second length in the first direction, a third region extending along the conveyance direction and having a third length in the conveyance direction, and a fourth region extending along the conveyance direction and having a fourth length in the conveyance direction. The device further includes a controller configured to cause at least one of the first, second, third and, fourth regions to emit a polarized wave towards the tag. Each of the first and second regions partially overlaps the third and fourth regions.

20 Claims, 11 Drawing Sheets



(52) **U.S. Cl.**
CPC ... ***G06K 7/10366*** (2013.01); ***G06K 19/07773*** (2013.01); *H04N 1/02472* (2013.01)

(58) **Field of Classification Search**
CPC G06K 7/10425; G06K 17/0025; G06K 19/0723; H04N 1/02472; H01Q 1/2208; H01Q 1/38; G03G 21/1896; G03G 15/5016; H04B 1/40
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2010/0303531	A1	12/2010	Fessler et al.
2015/0242667	A1	8/2015	Torchalski et al.

* cited by examiner

FIG. 1

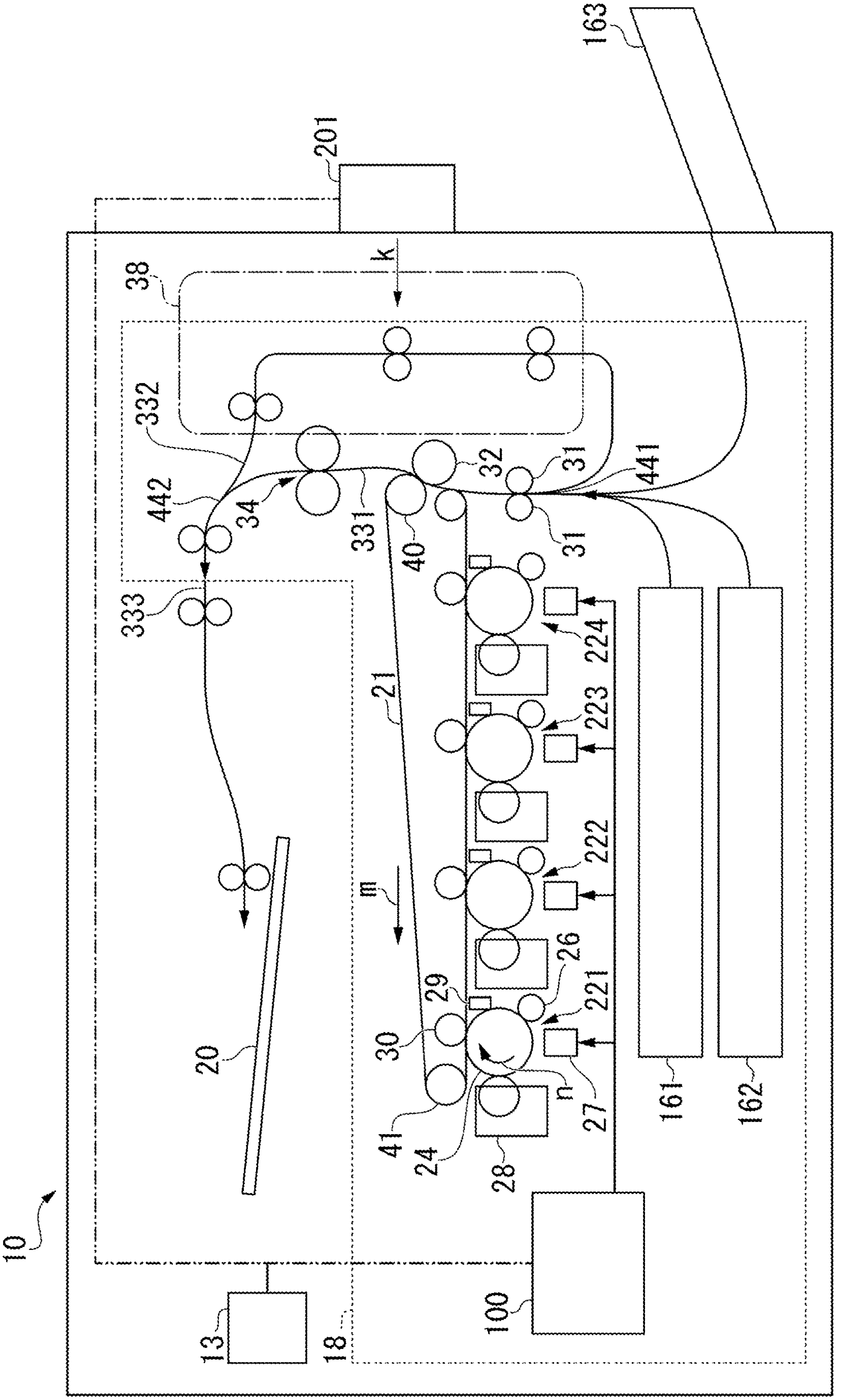

163
201
k
38
332
442
34
331
32
31
441
31
40
333
224
21
223
222
m
26
29
221
30
20
27
n
161
162
41
24
28
10
100
13
18

FIG. 2

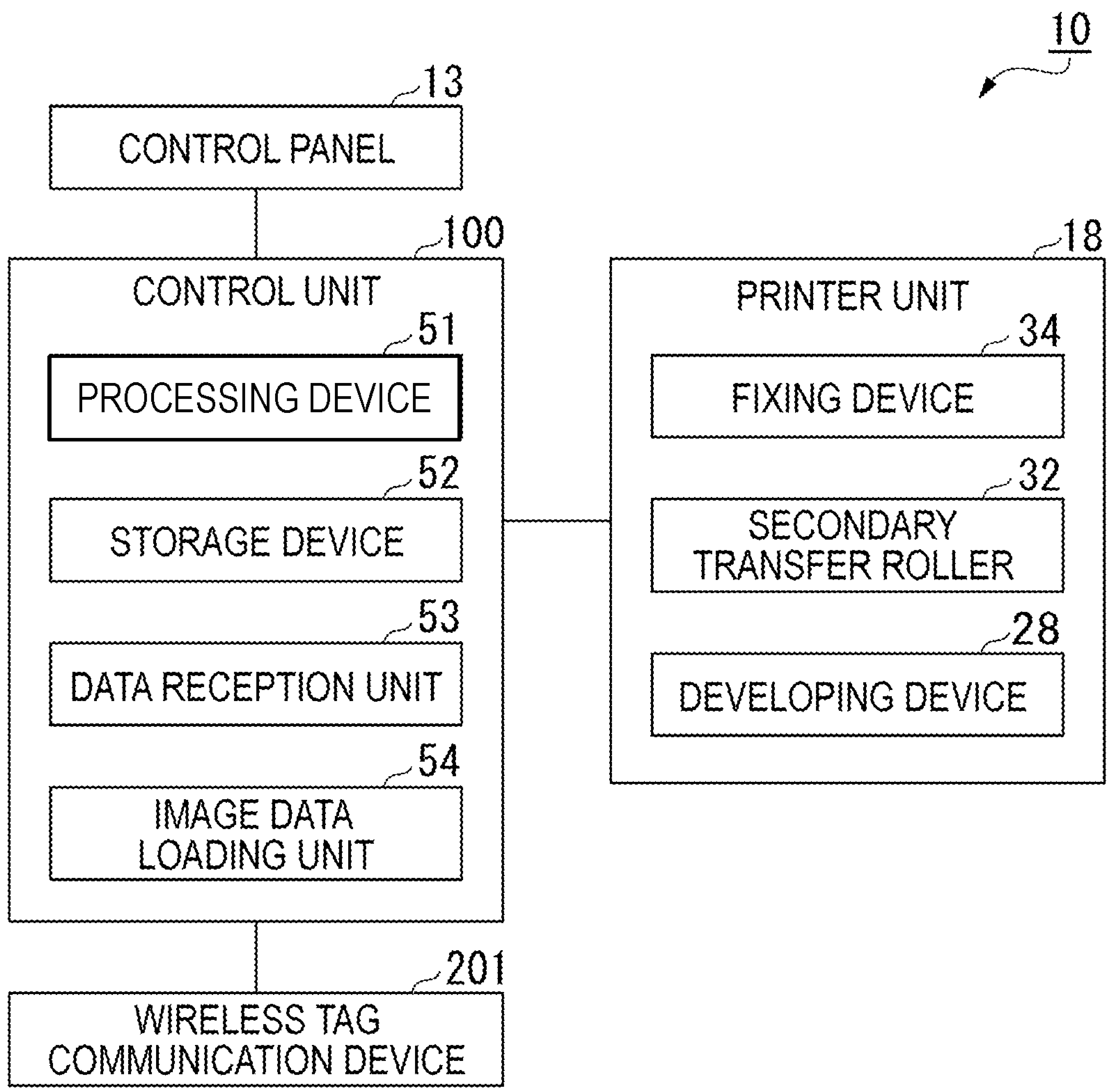

10
13
CONTROL PANEL
100
CONTROL UNIT
51
PROCESSING DEVICE
52
STORAGE DEVICE
53
DATA RECEPTION UNIT
54
IMAGE DATA
LOADING UNIT
18
PRINTER UNIT
34
FIXING DEVICE
32
SECONDARY
TRANSFER ROLLER
28
DEVELOPING DEVICE
201
WIRELESS TAG
COMMUNICATION DEVICE

FIG. 3

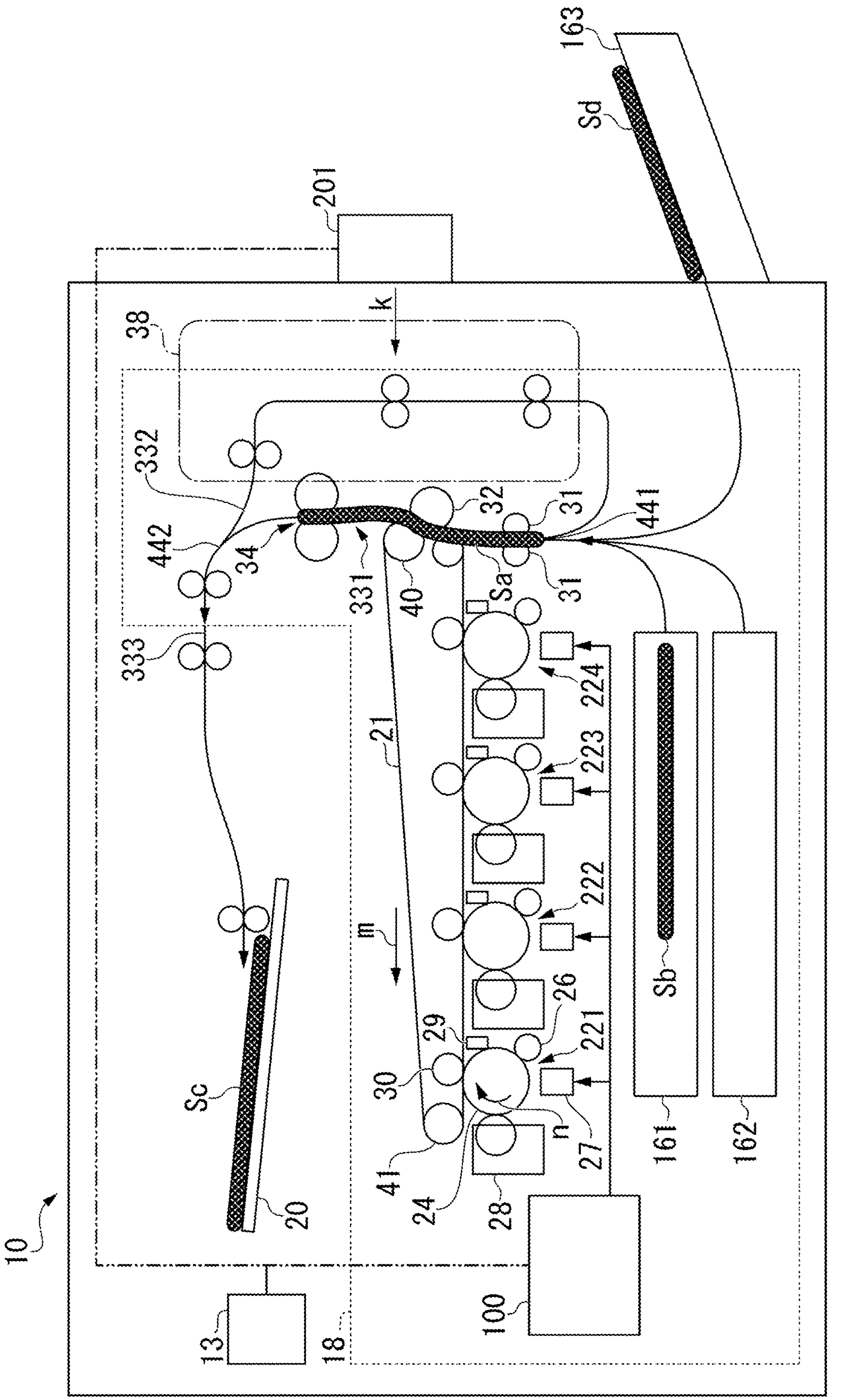

163
Sd
201
38
k
332
32
31
441
442
34
331
40
Sa
31
333
224
21
223
222
m
Sb
26
29
221
30
Sc
n
27
161
162
41
24
28
20
10
100
13
18

FIG. 4

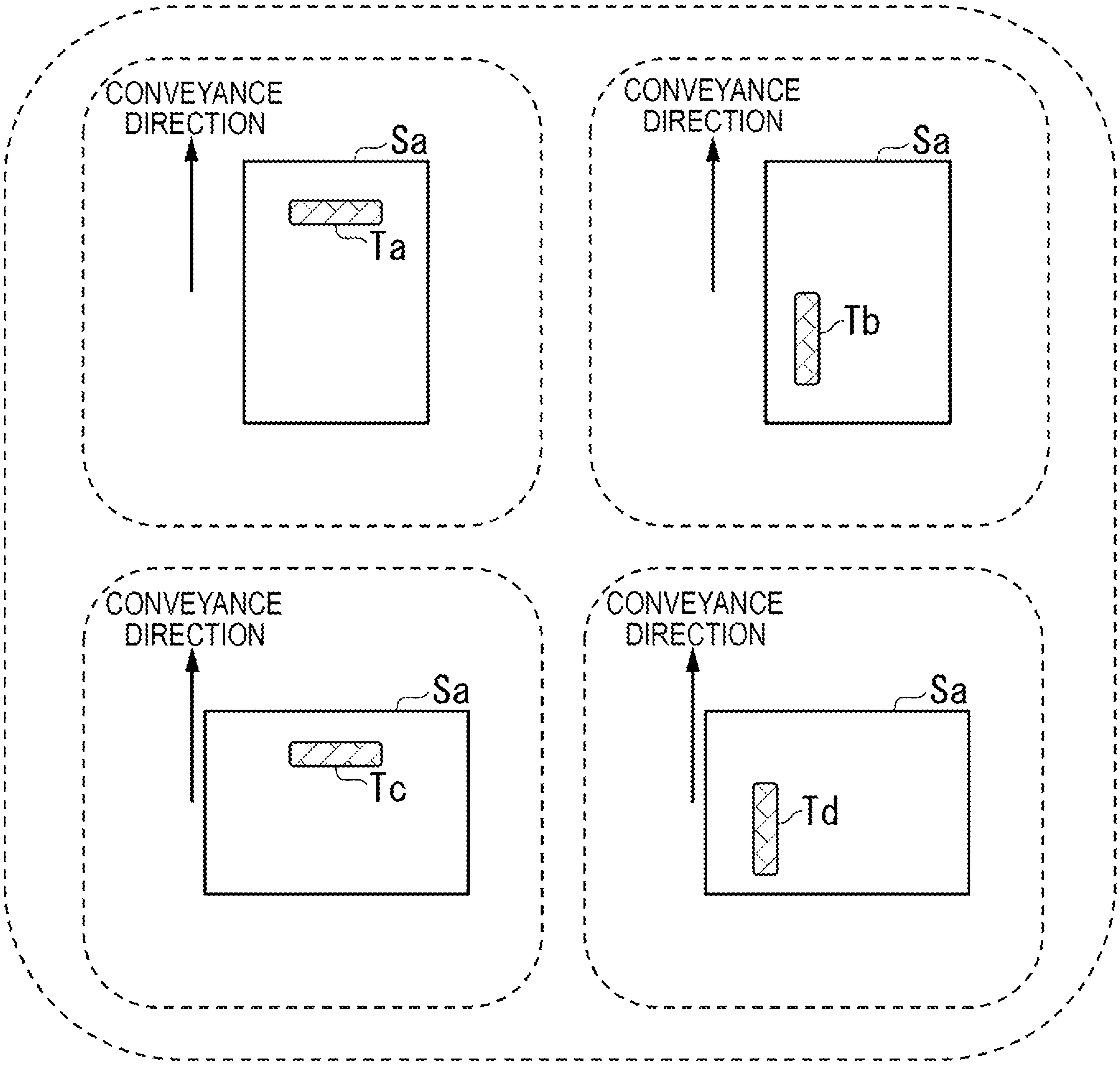

CONVEYANCE DIRECTION
Sa
Ta
CONVEYANCE DIRECTION
Sa
Tb
CONVEYANCE DIRECTION
Sa
Tc
CONVEYANCE DIRECTION
Sa
Td

FIG. 5

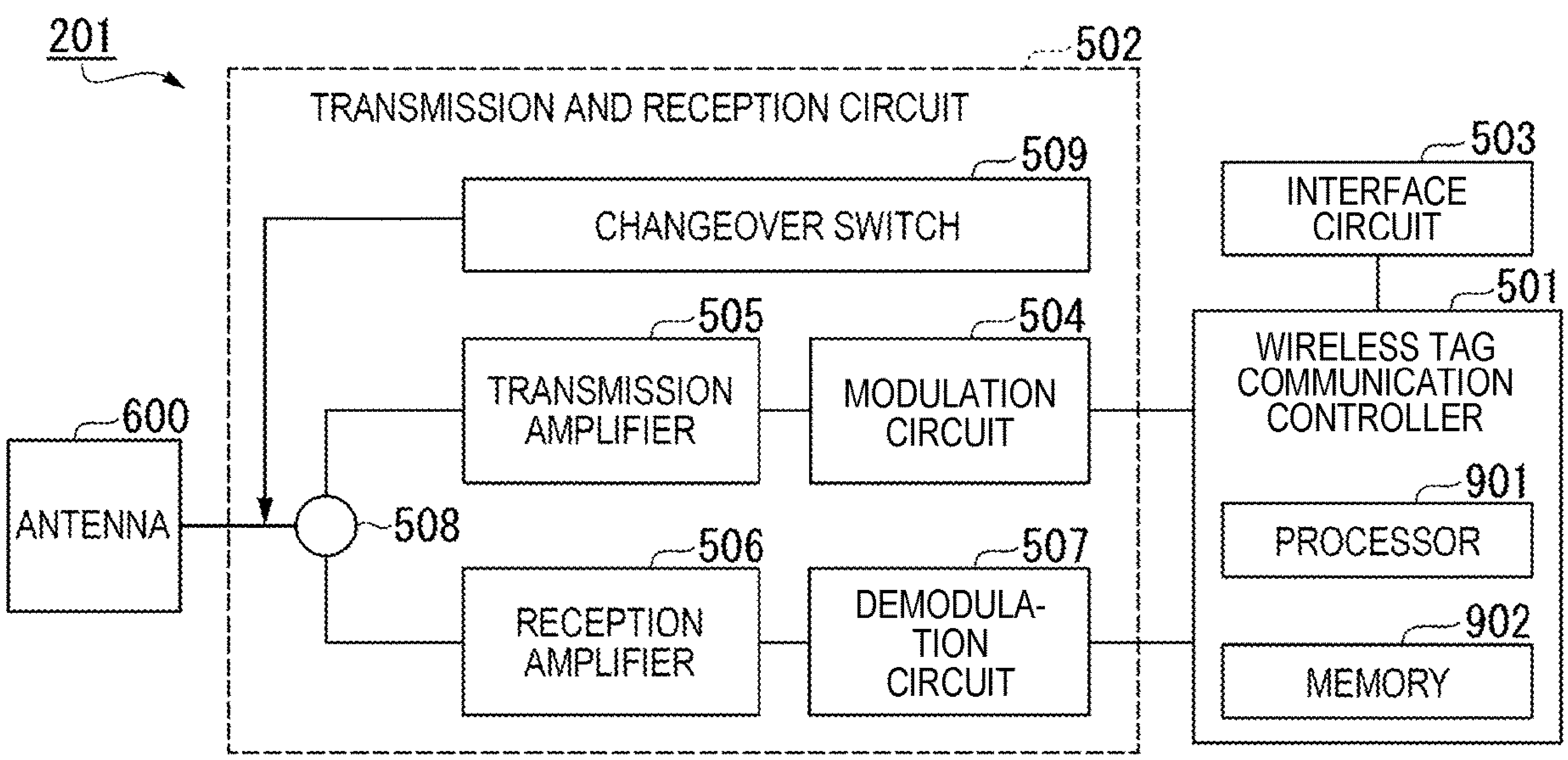
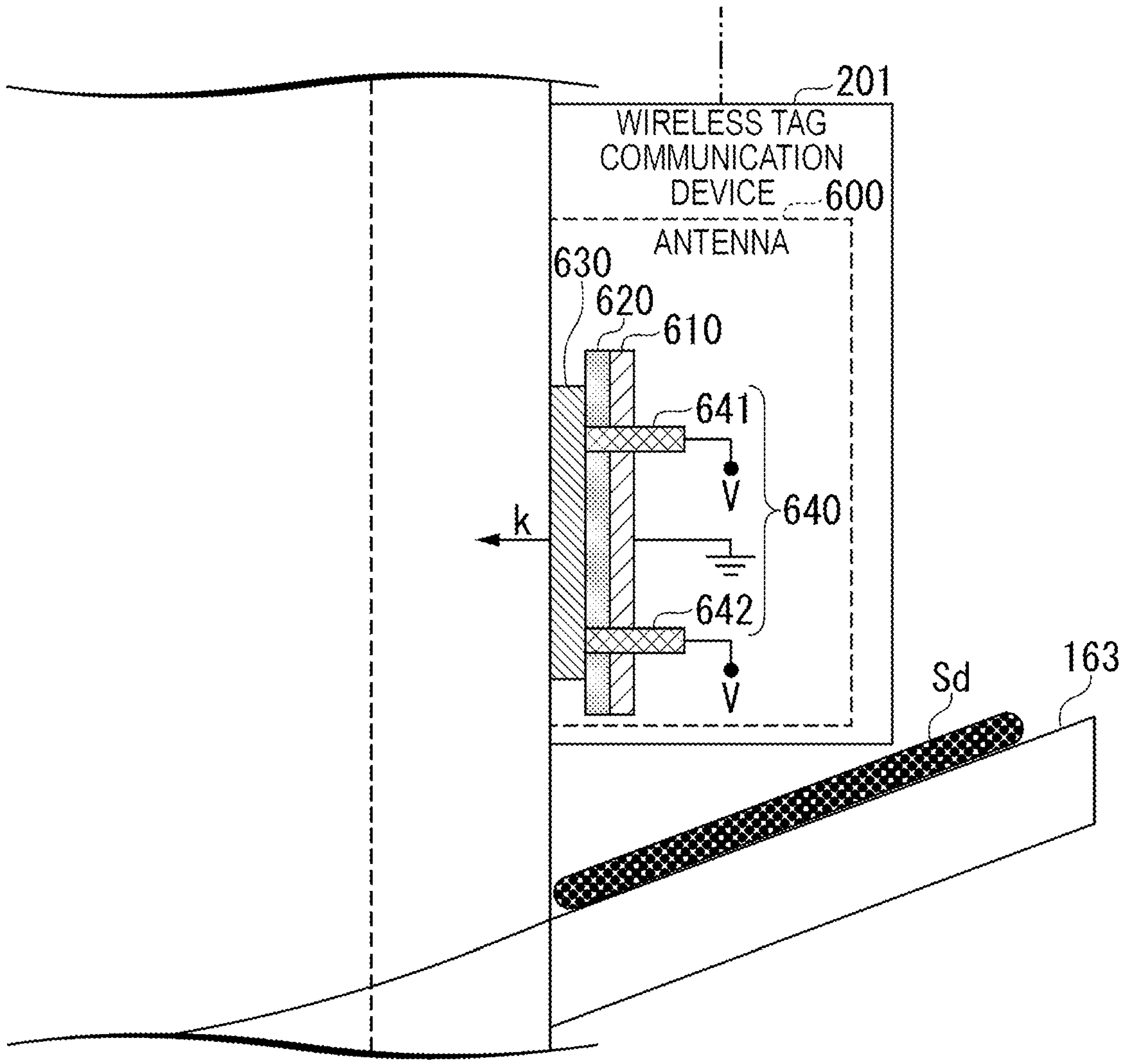

201
502
TRANSMISSION AND RECEPTION CIRCUIT
509
CHANGEOVER SWITCH
505
TRANSMISSION AMPLIFIER
504
MODULATION CIRCUIT
600
ANTENNA
508
506
RECEPTION AMPLIFIER
507
DEMODULATION CIRCUIT
503
INTERFACE CIRCUIT
501
WIRELESS TAG COMMUNICATION CONTROLLER
901
PROCESSOR
902
MEMORY

FIG. 6



201
WIRELESS TAG COMMUNICATION DEVICE
600
ANTENNA
630
620
610
641
V
640
k
642
V
Sd
163

FIG. 7

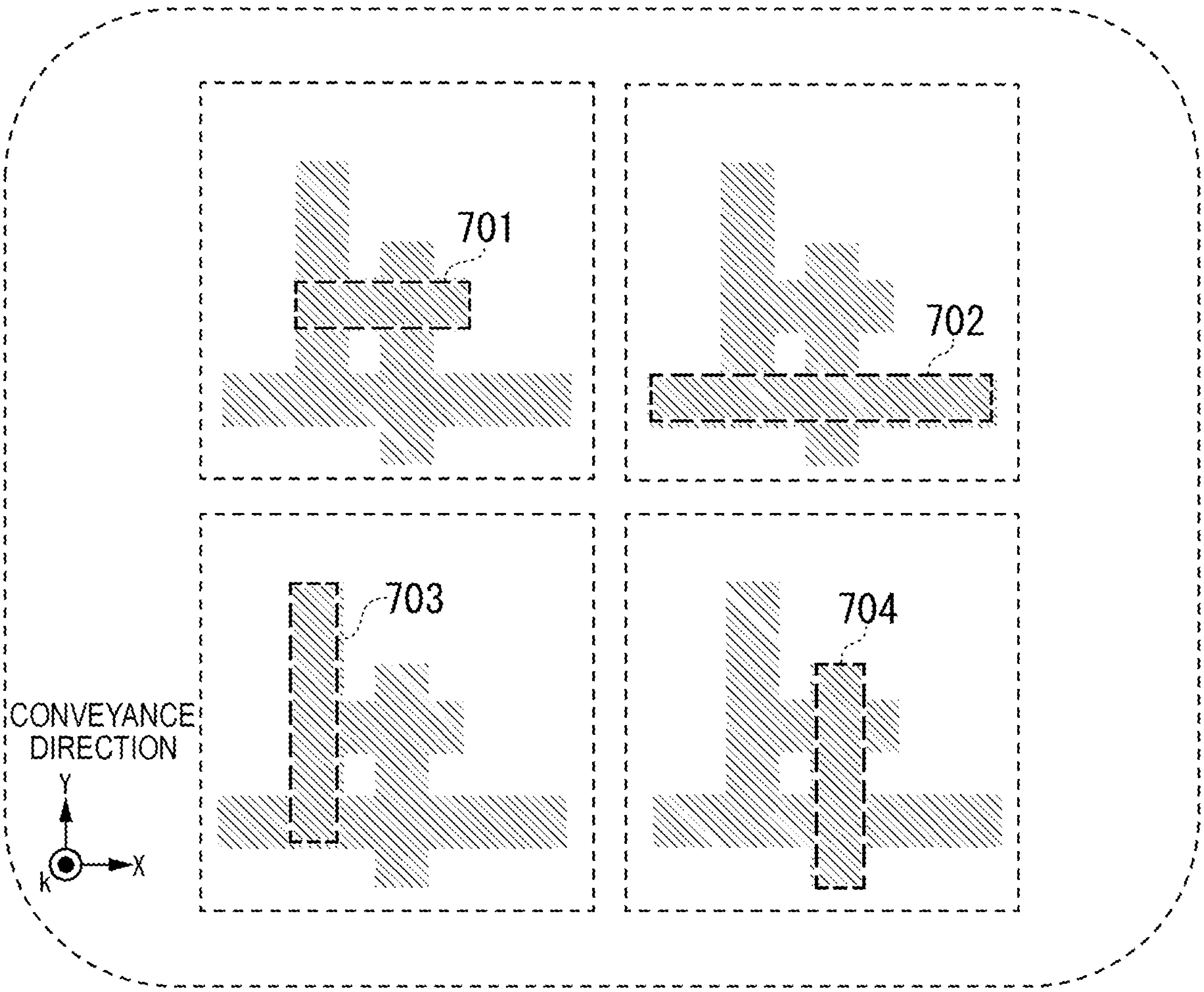


FIG. 8

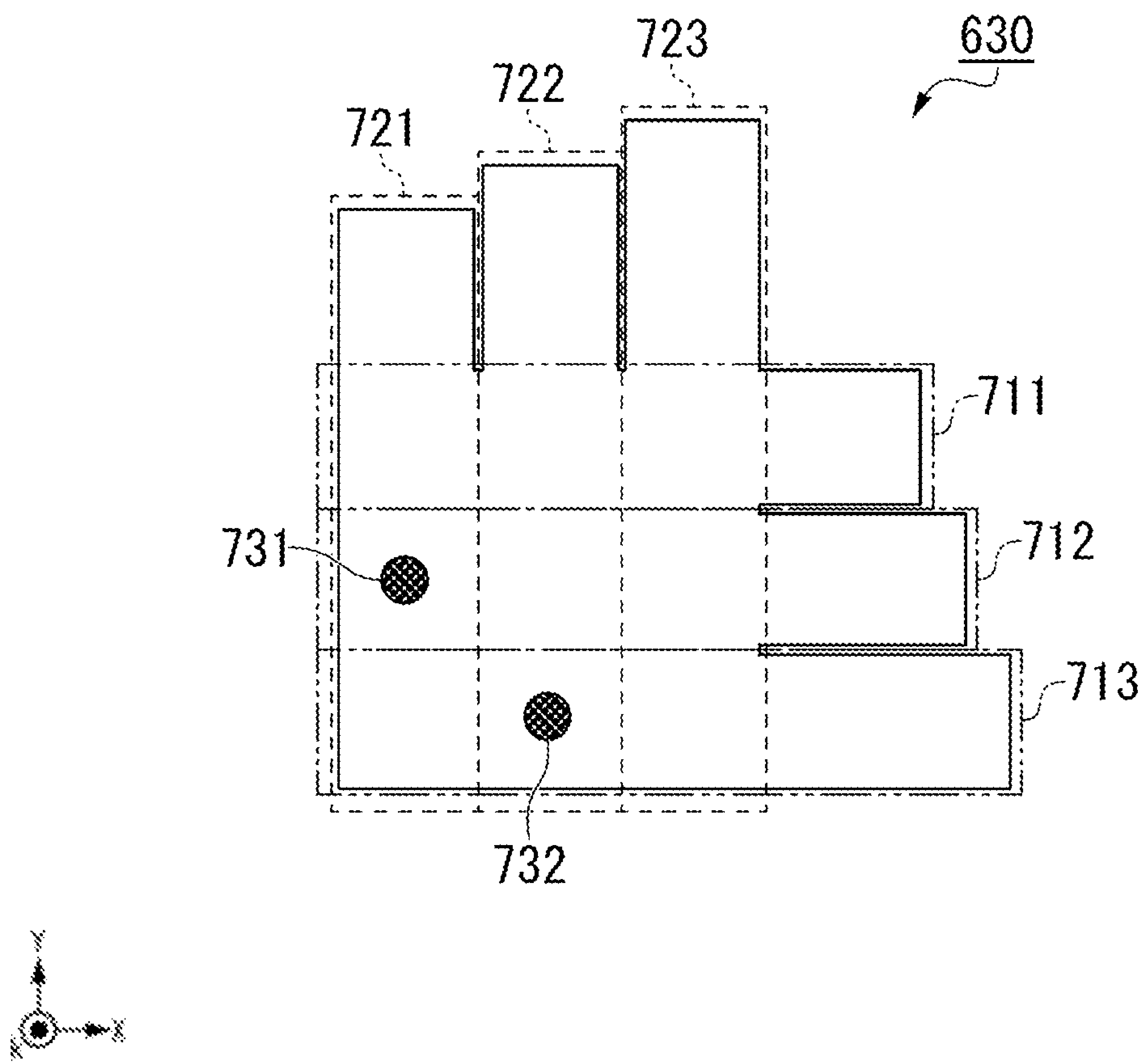
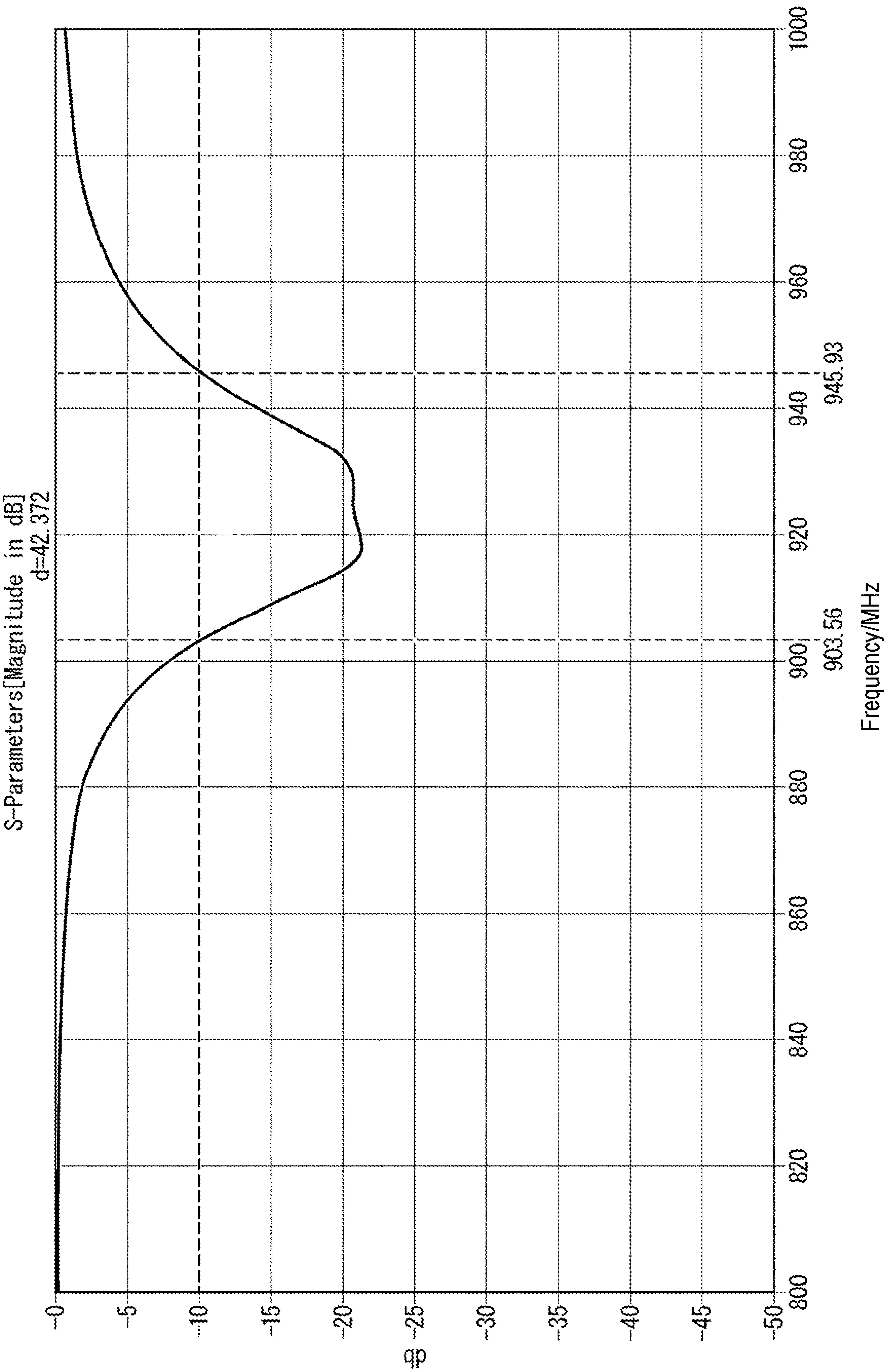


FIG. 9


S-Parameters[Magnitude in dB]
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945.93
903.56
Frequency/MHz
db
800
820
840
860
880
900
920
940
960
980
1000
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50

FIG. 10

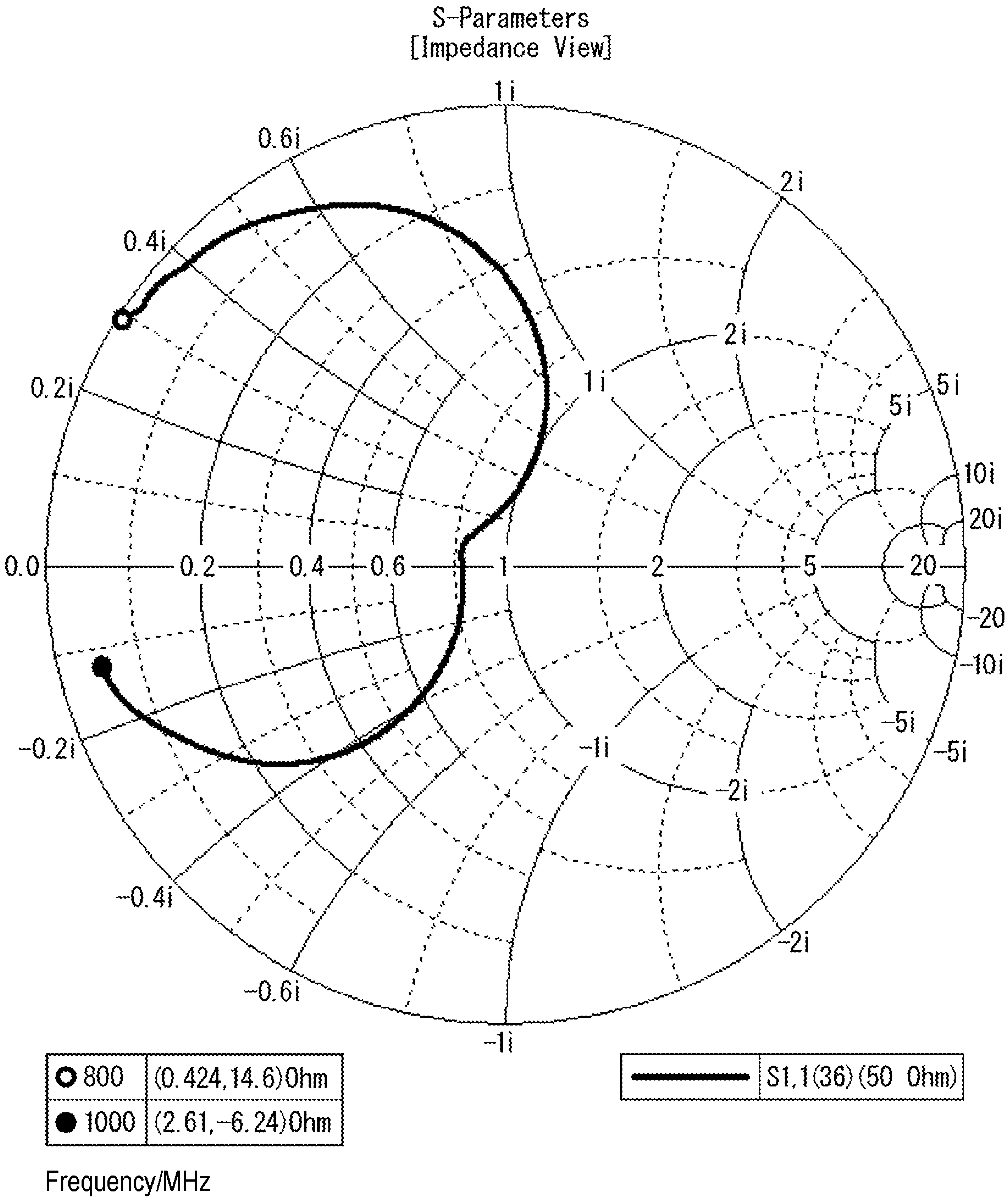
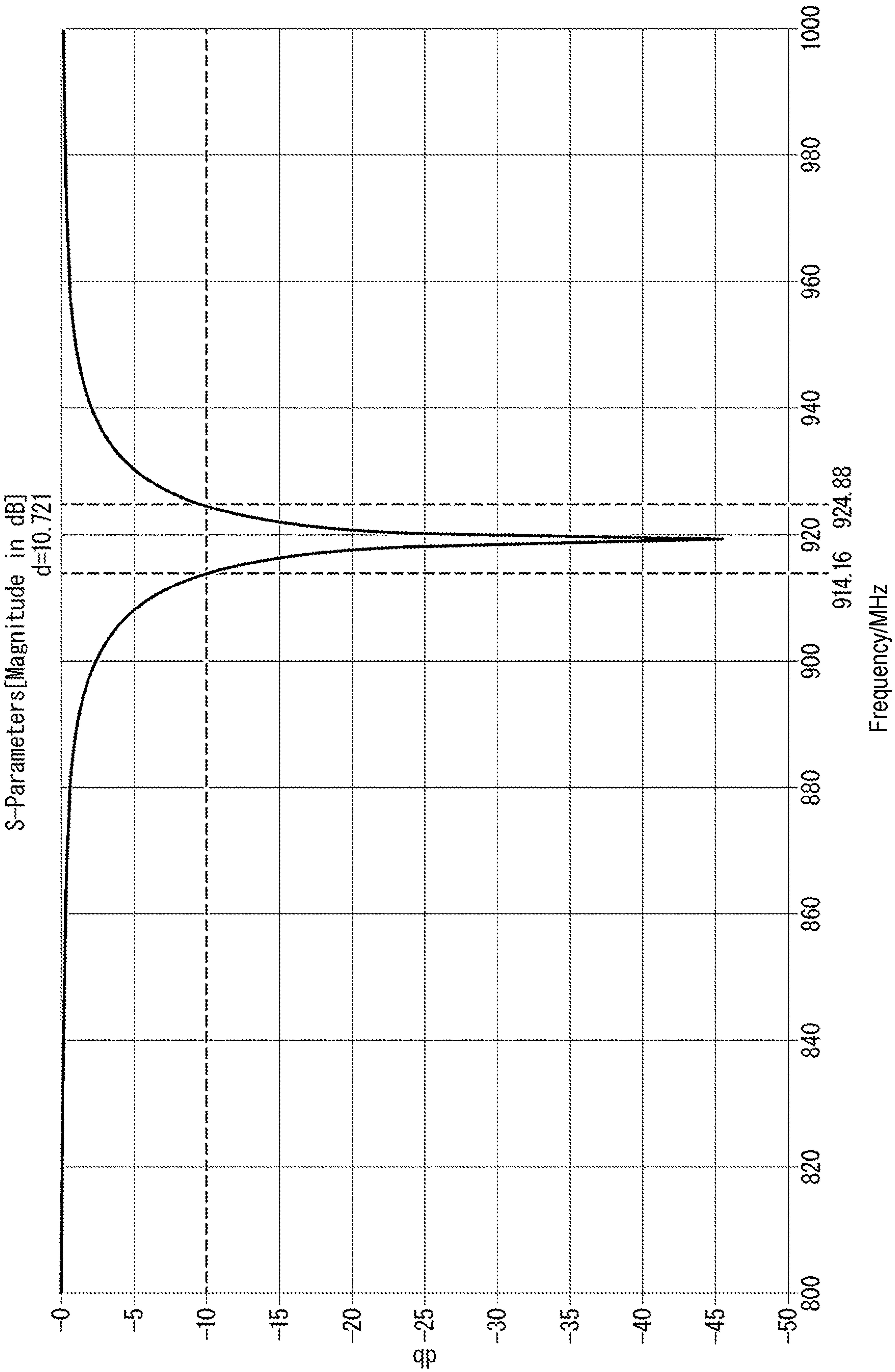

S-Parameters
[Impedance View]
1i
0.6i
0.4i
0.2i
0.0
0.2
0.4
0.6
1
2
5
20
2i
1i
5i
10i
20i
-20i
-10i
-5i
-1i
-2i
-0.2i
-0.4i
-0.6i
800 (0.424,14.6)Ohm
1000 (2.61,-6.24)Ohm
S1,1(36)(50 Ohm)
Frequency/MHz

FIG. 11


S-Parameters[Magnitude in dB]
d=10.721
914.16
924.88
Frequency/MHz
db
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
800
820
840
860
880
900
920
940
960
980
1000

WIRELESS TAG COMMUNICATION DEVICE AND SHEET PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2020-122404, filed Jul. 16, 2020, the entire contents of which are incorporated herein by reference.

FIELD

Embodiments described herein relate generally to a wireless tag communication device and a sheet processing apparatus.

BACKGROUND

There is an image forming apparatus that forms an image on a sheet on which a wireless tag, such as a radio frequency identifier (RFID), is attached. Such an image forming apparatus has an antenna capable of transmitting and receiving a radio wave to exchange information with the wireless tag. The antenna radiates a radio wave that can be received the wireless tag. More particularly, the radio wave emitted from the antenna needs to have a polarization plane that matches a polarization plane that can be received by the wireless tag. In addition, the radio wave needs to have a frequency within a frequency band that can be received by the wireless tag.

However, there are various different types of wireless tags that can be attached to a sheet. For example, the typical frequency band that can be received by a wireless tag may vary from country to country according to local standards or protocols. In such a case, an image forming apparatus capable of radiating radio waves only in a particular frequency band used in a specific country may not be able to communicate with a wireless tag used in another country. The differences in the types of usable wireless tags are not just dependent on the end-use country, and differences may also exist according to end-use application environments which may vary region to region even within a country. Such a problem associated with different potential wireless tag types may be more broadly found in any apparatus for processing a sheet or wireless tags.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagram illustrating an image forming apparatus according to an embodiment.

FIG. **2** is a functional block diagram of an image forming apparatus.

FIG. **3** is a diagram illustrating locations of a sheet in an image forming apparatus.

FIG. **4** is a diagram illustrating relationships between a location of a wireless tag on a sheet and a conveyance direction of the sheet.

FIG. **5** is a diagram illustrating a wireless tag communication device.

FIG. **6** is a diagram illustrating a side view of an antenna.

FIG. **7** is a diagram illustrating a shape of a radiation element.

FIG. **8** is a top view illustrating a radiation element.

FIG. **9** is a diagram illustrating frequency response characteristics of a wireless tag communication device.

FIG. **10** is a diagram illustrating frequency response characteristics of a wireless tag communication device.

FIG. **11** is a diagram illustrating frequency response characteristics of a comparative wireless tag communication device.

DETAILED DESCRIPTION

Embodiments provide a wireless tag communication device and a sheet processing apparatus that can exchange information with a wide variety wireless tag types.

In general, according to one embodiment, a wireless tag communication device for communicating with a wireless tag being conveyed by a conveyance mechanism includes an antenna with a plurality of radiation regions or elements from which a polarized radio wave can be emitted. The radiation regions include a first radiation region extending along a first direction crossing a conveyance direction of the wireless tag and having a first length in the first direction, a second radiation region extending along the first direction and having a second length that is different from the first length in the first direction, a third radiation region extending along the conveyance direction and having a third length in the conveyance direction, and a fourth radiation region extending along the conveyance direction and having a fourth length that is different from the third length in the conveyance direction. The device further comprises a controller configured to cause at least one of the first, second, third and, fourth radiation regions to emit a polarized wave towards the wireless tag. Each of the first and second radiation regions partially overlaps both the third radiation region and the fourth radiation region.

Hereinafter, a wireless tag communication device and a sheet processing apparatus according to one or more embodiments will be described with reference to the drawings.

In the following description, the same reference numerals are used to identify like features. The duplicated description of repeated features may be omitted.

FIG. **1** is a diagram illustrating an image forming apparatus **10** according to an embodiment. The image forming apparatus **10** is also referred to as a sheet processing apparatus or an image processing apparatus.

In FIG. **1**, the image forming apparatus **10** includes a control panel **13**, a wireless tag communication device **201**, and a printer unit **18**. The printer unit **18** includes a control unit **100**, paper feed cassettes **161** and **162**, and the like. The control unit **100** is a control circuit or a controller configured to control the control panel **13**, the wireless tag communication device **201**, and the printer unit **18**. The control unit **100** controls conveyance of a sheet in the printer unit **18**. The control of the sheet conveyance includes controlling a sheet conveyance timing, a sheet stop position, a sheet conveyance speed, and the like.

The control panel **13** includes an input key and a display unit. For example, the input key receives input from a user. For example, the display unit is a touch panel type. The display unit in such a case receives input from the user and displays information to the user according to the input(s). For example, the control panel **13** displays items related to an operation of the image forming apparatus **10** on the display unit. The control panel **13** notifies the control unit **100** of the items selected by the user.

The paper feed cassettes **161** and **162** accommodate sheets on which a wireless tag can be attached. The paper feed cassettes **161** and **162** can also accommodate a sheet on which a wireless tag is not attached. In the following description, unless otherwise specified, the sheet is provided with a wireless tag. A material such as paper or a plastic film is used for the sheet.

The printer unit **18** performs an image forming operation. For example, the printer unit **18** forms an image indicated by image data on a sheet. In the following description, forming of an image on a sheet is simply referred to as printing. The printer unit **18** includes an intermediate transfer belt **21**. The intermediate transfer belt **21** is supported by a driven roller **41**, a backup roller **40**, and the like. The printer unit **18** rotates the intermediate transfer belt **21** in a direction of arrow m shown in FIG. **1**.

The printer unit **18** includes four sets of image forming stations **221**, **222**, **223**, and **224**. The image forming stations **221**, **222**, **223** and **224** are used for image forming of Y (yellow), M (magenta), C (cyan), and K (black), respectively. The image forming stations **221**, **222**, **223**, and **224** are arranged below the intermediate transfer belt **21** along the intermediate transfer belt **21**.

Hereinafter, among the image forming stations **221**, **222**, **223**, and **224**, the Y (yellow) image forming station **221** will be described as an example. Since the image forming stations **222**, **223**, and **224** have substantially the same configuration as the image forming station **221**, detailed description thereof will be omitted.

The image forming station **221** includes an electrostatic charger **26**, an exposure scanning head **27**, a developing device **28**, and a photoreceptor cleaner **29**. The electrostatic charger **26**, the exposure scanning head **27**, the developing device **28**, and the photoreceptor cleaner **29** are arranged around a photoreceptor drum **24** that rotates in a direction of arrow n.

The image forming station **221** includes a primary transfer roller **30**. The primary transfer roller **30** faces the photoreceptor drum **24** via the intermediate transfer belt **21**.

The image forming station **221** charges the photoreceptor drum **24** with the electrostatic charger **26** and then selectively exposes the photoreceptor drum **24** with the exposure scanning head **27**. The image forming station **221** thus forms an electrostatic latent image on the photoreceptor drum **24**. The developing device **28** develops the electrostatic latent image on the photoreceptor drum **24** using a two-component developer formed of a toner and a carrier.

The primary transfer roller **30** primarily transfers a toner image formed on the photoreceptor drum **24** onto the intermediate transfer belt **21**. Each of the image forming stations **221**, **222**, **223**, and **224** forms a color toner image on the intermediate transfer belt **21** by the primary transfer roller **30**. The color toner image is formed by sequentially superimposing toner images of Y (yellow), M (magenta), C (cyan), and K (black). The photoreceptor cleaner **29** removes the toner remaining on the photoreceptor drum **24** after the primary transfer.

The printer unit **18** includes a secondary transfer roller **32**. The secondary transfer roller **32** faces a backup roller **40** via the intermediate transfer belt **21**. The secondary transfer roller **32** collectively and secondarily transfers the color toner image on the intermediate transfer belt **21** onto the sheet. In the following description, the term "toner image" may be either a color toner image or a toner image of only one color. The toner image may be a toner image using decolorable toner.

A conveyance path **331** is a conveyance path of the sheet extending from a confluence portion **441** to a branch portion **442**. A conveyance path **332** is a conveyance path that passes through a double-sided printing device **38** and extends from the branch portion **442** to the confluence portion **441**. A conveyance path **333** is a conveyance path of the sheet extending from the branch portion **442** to a paper discharge tray **20**.

The tip of the sheet picked up from a paper feed cassette **161**, a paper feed cassette **162**, or a manual feed tray **163** is abutted against a portion where two stopped registration rollers **31** are in contact with each other. An inclination of the sheet abutted against the registration roller **31** is corrected. The control unit **100** starts rotation of the registration roller **31** according to a position of the toner image on the rotating intermediate transfer belt **21** and moves the sheet to the secondary transfer roller **32**. The control unit **100** controls the secondary transfer roller **32** to secondarily transfer the toner image formed on the intermediate transfer belt **21** to the sheet. The control unit **100** causes the sheet to be conveyed along the conveyance path **331** and controls a fixing device **34** to form and fix a toner image onto the sheet. The control unit **100** causes the sheet to be discharged via the conveyance path **333**.

In the case of double-sided printing, the control unit **100** causes the sheet on which an image formed to be conveyed through the conveyance path **333**. After the entire sheet passes through the branch portion **442**, the control unit **100** causes the sheet to be switched back and conveyed through the conveyance path **332**. After that, the control unit **100** causes the sheet to be conveyed through the double-sided printing device **38**, the confluence portion **441**, the registration roller **31**, and the conveyance path **331**. Then, the control unit **100** controls the fixing device **34** to form and fix an image onto the back surface of the sheet. The control unit **100** causes the sheet to be discharged through the conveyance path **333**.

The wireless tag communication device **201** can communicate with the control unit **100**. The wireless tag communication device **201** reads information from the wireless tag and writes information to the wireless tag by communicating with the wireless tag on the sheet. The wireless tag communication device **201** transmits a signal towards a direction of arrow k shown in FIG. **1**. The signal is specifically a modulated radio wave. Information is written to the wireless tag of the sheet by the signal transmitted by the wireless tag communication device **201**.

When an image is formed in the printer unit **18**, an electrostatic latent image is formed on the photoreceptor drum **24** by the exposure scanning head **27** before secondarily transferred by the secondary transfer roller **32**. The electrostatic latent image formed on the photoreceptor drum is primarily transferred to the intermediate transfer belt **21** as a toner image. Furthermore, the toner image primarily transferred to the intermediate transfer belt **21** is secondarily transferred to the wireless tag sheet conveyed to the registration roller **31**.

Next, a functional block diagram of the image forming apparatus **10** will be described with reference to FIG. **2**.

In FIG. **2**, the image forming apparatus **10** includes the control unit **100**, the control panel **13**, the printer unit **18**, and the wireless tag communication device **201**.

The control unit **100** includes a processing device **51** (e.g., a processor) and a storage device **52**. The processing device **51** controls the control panel **13**, the printer unit **18**, and the wireless tag communication device **201** according to an image processing program stored in the storage device **52**. The control unit **100** outputs conveyance start information indicating that the sheet conveyance has been started.

The processing device **51** is, for example, a central processing unit (CPU), an application specific integrated circuit (ASIC), or the like.

The storage device **52** is a read only memory (ROM), a random access memory (RAM), a hard disk drive (HDD), a solid-state drive (SSD), or the like.

A data reception unit **53** receives, from a host, print data (for example, data described in a page description language) indicating an image to be printed. The host in this context is, for example, a personal computer (PC). The data reception unit **53** stores the print data received from the host in the storage device **52**.

An image data loading unit **54** converts the stored print data to data (for example, raster data) that can be printed by the printer unit **18** according to the printing parameters for the print data, and stores the converted data in the storage device **52**.

The printer unit **18** includes the fixing device **34**, the secondary transfer roller **32**, and the developing device **28**. The printer unit **18** forms an image on a sheet based on the converted data stored in the storage device **52**.

FIG. **3** is a diagram illustrating potential locations of a sheet in the image forming apparatus **10**. In FIG. **3**, a sheet Sb is a sheet placed in the paper feed cassette **161**. A sheet Sc is a sheet placed on the paper discharge tray **20**. A sheet Sd is a sheet placed on the manual feed tray **163**.

The sheet Sa is a sheet being conveyed along the conveyance path **331**. The wireless tag is provided on each sheet.

In FIG. **3**, the sheet (hereinafter, also referred to as "target sheet") on which information is to be written to the wireless tag is a sheet being conveyed along the conveyance path **331**. Thus, the sheet Sa is the target sheet.

In the state illustrated in FIG. **3**, the wireless tag communication device **201** transmits a signal towards the direction of arrow k. That is, the k-direction is a transmission direction of the signal transmitted by the wireless tag communication device **201**. For that reason, the k-direction is also a propagation direction of the radio wave radiated by the wireless tag communication device **201**.

Each wireless tag that receives the signal operates according to the received signal. The wireless tag stores, for example, information indicated by the received signal. The wireless tag responds to, for example, the wireless tag communication device **201**. Responding specifically means transmitting a signal. The wireless tag communication device **201** receives the signal transmitted from the wireless tag provided on each sheet. In the case of FIG. **3**, one of the wireless tags that receives the signal is the wireless tag provided on the sheet Sa. In FIG. **3**, the sheet Sa is being conveyed.

The wireless tag has a rectangular shape in a plane perpendicular to the k-direction having a longer side and a shorter side, and, when wavelengths of the radio waves are the same, a polarized wave whose polarization plane is parallel to the longer side (major axis) interacts more strongly with the wireless tag than a polarized wave whose polarization plane is perpendicular to the longer side.

Stronger interaction in this context means that the probability that the radio wave passes through the wireless tag without generating a response is low or, alternatively, the probability that the radio wave reaching the wireless tag will be absorbed or reflected by the wireless tag is high. For this reason, in the wireless tag communication device **201**, a radio wave whose polarization plane is parallel to the longer side of the wireless tag is desirably used for exchanging information with the wireless tag from the viewpoint of reducing power consumption and the frequency of communication errors. A communication error in this context means that information cannot be appropriately exchanged between the wireless tag communication device **201** and the wireless tag.

FIG. **4** is a diagram illustrating relationships between a location of a wireless tag on a sheet and a conveyance direction of the sheet. In FIG. **4**, each of wireless tags Ta, Tb, Tc, and Td is provided on the sheet Sa being conveyed along the conveyance path **331**. The tag Ta is an example of the wireless tag provided on the sheet Sa so that the longer side of the tag Ta is perpendicular to the conveyance direction and perpendicular to the longer side of the paper surface. The tag Tb is an example of the wireless tag provided on the sheet Sa so that the longer side of the tag Tb is parallel to the conveyance direction and parallel to the longer side of the sheet Sa. The tag Tc is an example of the wireless tag provided on the sheet Sa so that the longer side of the tag Tc is perpendicular to the conveyance direction and parallel to the longer side of the sheet Sa. The tag Td is an example of the wireless tag provided on the sheet Sa so that the longer side of the tag Td is parallel to the conveyance direction and perpendicular to the longer side of the sheet Sa. Although FIG. **4** illustrates an example in which one wireless tag is arranged on one sheet, a plurality of radio tags may be arranged on one sheet.

The sheet conveyance direction is, for example, a direction perpendicular to the k-direction in FIG. **3** and a direction from the bottom to the top on the paper surface of FIG. **3**. Since the wireless tag is provided on the sheet, the sheet conveyance direction is also the wireless tag conveyance direction.

FIG. **5** is a diagram illustrating the wireless tag communication device **201**.

The wireless tag communication device **201** includes an antenna **600**, a wireless tag communication controller **501**, a transmission and reception circuit **502**, and an interface circuit **503**.

The antenna **600** transmits a signal. The antenna **600** receives an incoming signal. The carrier of the signal transmitted by the antenna **600** is a radio wave. The carrier of the signal received by the antenna **600** is a radio wave.

The wireless tag communication controller **501** includes a processor **901** such as a CPU and a memory **902**. The processor **901** of the wireless tag communication controller **501** executes a program(s) stored in the memory **902**. The wireless tag communication controller **501** controls the operation of each circuit or unit included in the wireless tag communication device **201**. A write threshold value (e.g., a signal strength value below which writing is not attempted) can be stored in the memory **902** in advance.

The wireless tag communication controller **501** receives, for example, sheet conveyance start information. The wireless tag communication controller **501** controls transmission of a signal by controlling each circuit included in the wireless tag communication device **201**, for example. The wireless tag communication controller **501** causes the signal received by the antenna **600** to be demodulated, for example, by controlling each circuit included in the wireless tag communication device **201**. The wireless tag communication controller **501** measures, for example, the elapsed time since receiving the conveyance start information.

The transmission and reception circuit **502** includes a modulation circuit **504**, a transmission amplifier **505**, a reception amplifier **506**, a demodulation circuit **507**, a circulator **508**, and a changeover switch **509**.

The modulation circuit **504** modulates the radio wave radiated by the wireless tag communication device **201**. More specifically, a voltage modulated by the control of the wireless tag communication controller **501** is applied to the modulation circuit **504**, and the modulation circuit **504** generates a modulated current by application of the voltage. After the current generated by the modulation circuit **504** flows through the transmission amplifier **505**, the antenna **600** transmits the radio wave. As described above, the radio wave is modulated by the modulation circuit **504** and radiated from the antenna **600**, and therefore the transmitted radio wave from antenna **600** incorporates a signal to be transmitted by the wireless tag communication device **201**.

The transmission amplifier **505** controls intensity of the signal transmitted by the wireless tag communication device **201**. The circulator **508** separates the signal transmitted by the antenna **600** from the signal received by the antenna **600**.

The changeover switch **509** switches a voltage application destination, that is, the target to which the current modulated by the modulation circuit **504** and amplified by the transmission amplifier **505** flows. Specifically, the changeover switch **509** switches a connection destination of the transmission amplifier **505** to one of power-feeding lines **641** and **642**, which will be described later. The changeover switch **509** is a radio frequency (RF) switch such as a single pole double throw switch. The operation of the changeover switch **509** is controlled by the wireless tag communication controller **501**. The changeover switch **509** switches, under the control of the wireless tag communication controller **501**, the voltage application destination.

The reception amplifier **506** controls the intensity of the signal received by the antenna **600** to a predetermined intensity. The demodulation circuit **507** demodulates the signal received by the antenna **600**.

The interface circuit **503** is a circuit that electrically connects the wireless tag communication controller **501** and the control unit **100**.

FIG. **6** is a diagram illustrating a side view of the antenna **600**. The antenna **600** is a microstrip antenna including a ground conductor plate **610**, a dielectric substrate **620**, and a radiation element **630**. The ground conductor plate **610** is a grounded conductor. The dielectric substrate **620** is a dielectric material in contact with the ground conductor plate **610**.

The radiation element **630** is a conductor positioned on a side of the dielectric substrate **620** on which the ground conductor plate **610** is not disposed, and is a conductor in contact with the dielectric substrate **620**. The radiation element **630** is connected to the power-feeding lines **641** and **642** penetrating the dielectric substrate **620** and the ground conductor plate **610**. The power-feeding lines **641** and **642** are conductive wires. When a voltage is applied through either of the power-feeding lines **641** and **642**, the radiation element **630** radiates the radio wave generated by the current generated by the applied voltage. The radiated radio wave is a signal. A wave vector of the radio wave radiated by the radiation element **630** is the vector directed towards the k-direction. Hereinafter, when the power-feeding line **641** and the power-feeding line **642** are not distinguished, the power-feeding lines **641** and **642** are referred to as a power-feeding line **640**. One end of the power-feeding line **640** not in contact with the radiation element **630** is connected to the changeover switch **509**.

For the sake of simplicity, a plane perpendicular to the k-direction is referred to as an XY-plane. Two vectors on the XY-plane and orthogonal to each other a referenced in this description. One vector that is perpendicular to the conveyance direction of the sheet as conveyed on the conveyance path **331** is referred to as an X-vector. Another vector that is perpendicular to the X-vector (e.g., parallel to the conveyance direction) is referred to as a Y-vector.

Shapes of the surfaces of the radiation element **630** perpendicular to the k-direction are substantially the same regardless of the position along the k-direction. The length of the radiation element **630** in the k-direction is preferably shorter than the wavelength of the radio wave to be radiated by the radiation element **630**, and particularly preferably less than one-fourth of the wavelength.

FIG. **7** is a diagram illustrating a shape (hereinafter referred to as "radiation element shape") of the radiation element **630** in the XY-plane. The direction orthogonal to plane of the paper surface of FIG. **7** is parallel to the k-direction.

A plane (hereinafter referred to as a "radiation element plane") surrounded by the radiation element shape has a first radiation region **701**, a second radiation region **702**, a third radiation region **703**, and a fourth radiation region **704**. That is, the first radiation region **701**, the second radiation region **702**, the third radiation region **703**, and the fourth radiation region **704** are positioned in the same plane. The first radiation region **701** and the second radiation region **702** are regions having a shape that satisfies the condition that the length in the direction of the X-vector is longer than the length in the direction of the Y-vector. The third radiation region **703** and the fourth radiation region **704** are regions having a shape that satisfies the condition that the length in the direction of the Y-vector is longer than the length in the direction of the X-vector.

The first radiation region **701** and the second radiation region **702** are regions having different lengths in the X-vector direction, and are regions that do not come into contact or overlap each other. The first radiation region **701** shares a part with the third radiation region **703** and the fourth radiation region **704**. The second radiation region **702** shares a part with the third radiation region **703** and the fourth radiation region **704**.

The third radiation region **703** and the fourth radiation region **704** are regions having different lengths in the direction of the Y-vector, and are regions that do not come into contact or overlap each other. The third radiation region **703** shares a part thereof with the first radiation region **701** and the second radiation region **702**. The fourth radiation region **704** shares a part thereof with the first radiation region **701** and the second radiation region **702**.

FIG. **8** is a top view illustrating the radiation element **630**. The direction perpendicular to the paper surface of FIG. **8** is parallel to the k-direction.

A region **711** in FIG. **8** corresponds to the first radiation region **701**. A region **712** in FIG. **8** corresponds to the second radiation region **702**. A region **721** in FIG. **8** corresponds to the third radiation region **703**. A region **722** in FIG. **8** corresponds to the fourth radiation region **704**.

In FIG. **8**, the radiation element plane may include the first radiation region **711**, the second radiation region **712**, the third radiation region **721**, and the fourth radiation region **722**, and may further include a first type additional region **713** and/or a second type additional region **723** in addition to the first radiation region **711**, the second radiation region **712**, the third radiation region **721**, and the fourth radiation region **722**. That is, the first radiation region **711**, the second radiation region **712**, the third radiation region **721**, the fourth radiation region **722**, the first type additional region **713**, and the second type additional region **723** are positioned in the same plane.

The first type additional region **713** is a region having a shape that satisfies the condition that the length in the direction of the X-vector is longer than the length in the direction of the Y-vector, and is a region different from the first radiation region **711** and the second radiation region **712**. The first type additional region **713** is a region that does not come into contact with or overlap other first type additional regions. The first type additional region **713** is a region that does not come into contact with or overlap the first radiation region **711** and the second radiation region **712**. The first type additional region **713** shares a part thereof with the third radiation region **721**, the fourth radiation region **722**, and the second type additional region **723**.

The second type additional region **723** is a region having a shape that satisfies the condition that the length in the direction of the Y-vector is longer than the length in the direction of the X-vector, and is a region different from the third radiation region **721** and the fourth radiation region **722**. The second type additional region **723** is a region that does not come into contact with or overlap other second type additional regions. The second type additional region **723** is a region that does not come into contact with or overlap the third radiation region **721** and the fourth radiation region **722**. The second type additional region **723** shares a part thereof with the first radiation region **711**, the second radiation region **712**, and the first type additional region **713**.

The number of first type additional regions **713** in the radiation element plane does not need to be one, and may be two or more. The number of second type additional regions **723** in the radiation element plane does not need to be one, and may be two or more.

The radiation element **630** includes power-feeding points **731** and **732**. More specifically, at the power-feeding point **731**, the power-feeding line **641** and the radiation element **630** are in contact with each other, and at the power-feeding point **732**, the power-feeding line **642** and the radiation element **630** are in contact with each other.

FIGS. **9** and **10** are diagrams illustrating frequency response characteristics of the wireless tag communication device **201** regarding the radio wave transmitted and received by the wireless tag communication device **201**, acquired through an experiment. More specifically, FIGS. **9** and **10** are diagrams the frequency response characteristics of the wireless tag communication device **201** regarding the radio wave transmitted and received by the wireless tag communication device **201** including the radiation element **630** of FIG. **8**. In particular, FIG. **10** illustrates the experimental results shown by the Smith chart. As the frequency response characteristics, values of the S parameter were measured.

In the experiment, a material of the radiation element **630** was copper. For that reason, the conductivity was 5.8×10^7 (S/m). In the experiment, the lengths of the regions **711**, **712**, and **713** in the direction of the X-vector were 77 mm, 72 mm, and 67 mm, respectively, and the lengths of the regions **711**, **712**, and **713** in the direction of the Y-vector were 10 mm, 21 mm, and 20 mm, respectively. In the experiment, the lengths of the regions **721**, **722**, and **723** in the direction of the X-vector were 10 mm, 21 mm, and 20 mm, respectively, and the lengths of the regions **721**, **722**, and **723** in the direction of the Y-vector were 67 mm, 72 mm, and 77 mm, respectively.

In the experiment, the material of the dielectric substrate **620** was flame retardant type 4 (FR4), and a dielectric constant was 4.6. The length in the k-direction was 1.53 mm. The total length of the ground conductor plate **610** and the radiation element **630** in the k-direction was 0.07 mm. In the experiment, the plane of the dielectric substrate **620** in contact with the radiation element **630** had a length of 130 mm in the direction of the X-vector and a length of 130 mm in the direction of the Y-vector.

In the experiment, the material of the ground conductor plate **610** was copper. For that reason, the conductivity was 5.8×10^7 (S/m). In the experiment, the length of the ground conductor plate **610** in the k-direction was 0.035 mm. In the experiment, the plane of the ground conductor plate **610** in contact with the dielectric substrate **620** had a length of 130 mm in the direction of the X-vector and a length of 130 mm in the direction of the Y-vector.

FIGS. **9** and **10** illustrate shows a range of approximately 42 MHz in width centered on 920 MHz where S parameter **S11** is −10 dB or less.

Next, the results of an experiment (hereinafter referred to as "comparative experiment") for comparison with the results of the experiment in FIGS. **9** and **10** will be described with reference to FIG. **11**. In the comparative experiment, a square patch antenna was used instead of the antenna **600**. The square patch antennas used in the comparative experiment differed only in that the shape of the conductor radiating the radio wave in the XY-plane was square instead of the shape illustrated in FIG. **8**. The length of one side of the shape in the XY-plane of the square patch antenna used in the comparative experiment was 75 mm.

FIG. **11** is a diagram illustrating frequency response characteristics of a wireless tag communication device having the comparative square patch antenna. FIG. **11** illustrates a range of approximately 10 MHz in width centered on 920 MHz where the S parameter **S11** is −10 dB or less.

The results shown in FIGS. **9**, **10** and **11** illustrate that the antenna **600** is an antenna having a wider band than the square patch antenna.

Here, the reason why the antenna **600** has a wider band than the square patch antenna will be explained. Hereinafter, for the sake of simplicity, when the first radiation region **711**, the second radiation region **712**, the third radiation region **721**, the fourth radiation region **722**, the first type additional region **713**, and the second type additional region **723** are not distinguished, these regions are referred to as radiation regions. A radiation region in the radiation element **630** has a shape in which the length in the direction of a predetermined side is longer than the length in the direction of another side orthogonal to the predetermined side. That is, the shape of the radiation region has a longer side and a shorter side. Such a shape is similar to that of the antenna element. For that reason, each radiation region radiates a polarized wave whose polarization plane is parallel to the longer side of the radiation region and having a resonance frequency determined by the length of the longer side. Specifically, the resonance frequency is a frequency of a radio wave having a wavelength, a half of which is equal to the length of the longer side.

For example, the first radiation region **711** in FIG. **8** has a shape whose longer side is parallel to the X-axis and shorter side is parallel to the Y-axis. For that reason, the first radiation region **711** in FIG. **8** radiates the radio wave whose polarization plane is parallel to the X-axis and whose wavelength is equal to twice the length of the longer side of the first radiation region **711**. For example, the third radiation region **721** in FIG. **8** has a shape whose longer side is parallel to the Y-axis and shorter side is parallel to the X-axis. For that reason, the third radiation region **721** in FIG. **8** radiates the radio wave whose polarization plane is parallel to the Y-axis and whose wavelength is equal to twice the length of the longer side of the third radiation region **721**.

For that reason, the radiation element **630** having a plurality of shapes of radiation regions can radiate a plurality of types of radio waves having different combinations of polarization planes and wavelengths. That is, the antenna **600** can emit a radio wave of a wider band than an antenna having only a single shape of radiation region such as a square patch antenna, and can radiate a plurality of radio waves having different polarization planes unlike the antenna having only one type of radiation region.

In the radiation element **630**, adjacent radiation regions whose longer sides are parallel are electrically connected by a part of radiation regions whose longer sides cross the longer sides of the adjacent radiation regions. For example, in FIG. **8**, the first radiation region **711** and the second radiation region **712** are conducted by a part of the third radiation region **721**, a part of the fourth radiation region **722**, and a part of the second type additional radiation region **723** along the y-axis. Hereinafter, a radiation region positioned in the space between adjacent radiation regions whose longer sides are parallel and which conducts the adjacent radiation regions is referred to as a conducting region. For example, a part of the third radiation region **721** that conducts the first radiation region **711** and the second radiation region **712** along the y-axis is such a conducting portion.

For that reason, the first radiation region **711** and the second radiation region **712** can radiate not only the radio wave having a wavelength corresponding to the length of the longer side of each region but also the radio wave having a wavelength corresponding to the length of the longer side of a region obtained by adding the conducting portion to each region. For that reason, the antenna **600** can radiate the radio waves in a wider band than an antenna having just a plurality of types of radiation regions in a state where the plurality of radiation regions spatially separated from each other.

Furthermore, the antenna **600** can switch and radiate radio waves whose polarization planes are orthogonal to each other while having a structure in which a part of a plurality of radiation regions having longer sides extending towards different directions is shared. That is, the antenna **600** does not have a structure in which a plurality of radiation elements having longer sides extending towards different directions are spatially separated in order to radiate radio waves whose polarization planes are different. For that reason, the antenna **600** can reduce an occupancy area of the radiation element **630** for radiating radio waves having different polarization planes.

The wireless tag communication device **201** configured as described above includes the antenna **600** capable of radiating a plurality of types of polarized waves having a plurality of polarization planes or different frequencies. For that reason, the probability that the polarized wave radiated by the wireless tag communication device **201** is received by the radio tag is higher than the probability that the polarized wave radiated by a conventional device that radiates only one type of polarized wave is received by the radio tag. For that reason, the wireless tag communication device **201** can reduce the chance that information cannot be exchanged with the wireless tag due to the difference in the type of the wireless tag.

For that reason, the image forming apparatus **10** configured in this way can reduce the chance that information cannot be exchanged with the wireless tag due to the difference in the type of the wireless tag. This is not limited to the image forming apparatus **10**, but the same applies to another sheet processing apparatus provided with the wireless tag communication device **201**.

The image forming apparatus **10** may be a bar code printer used for managing a receipt and shipment of goods, or a reader that reads a sheet attached to goods displayed or sold in a retail store such as an apparel store. In such a case, the sheet provided with the wireless tag is a sheet or a tag attached to goods.

MODIFICATION EXAMPLE

One end of the longer side of the first radiation region **711** and one end of the longer side of the second radiation region **712** do not necessarily need to be aligned as illustrated in FIG. **8**. That is, one end of the longer side of the first radiation region **711** and one end of the longer side of the second radiation region **712** may have a positional relationship as illustrated in FIG. **7**. The same applies to the first type additional region **713**. That is, one end of the longer side of the first radiation region **711** and one end of the longer side of the first type additional region **713** do not necessarily need to be aligned, and one end of the longer side of the second radiation region **712** and one end of the longer side of the first type additional region **713** do not necessarily need to be aligned.

When a plurality of first type additional regions exist, one end of the longer side of one first type additional region and one ends of the longer sides of other first type additional regions do not necessarily need to be aligned. However, when the ends are aligned, the effect that the gain is higher is obtained. When the ends are not aligned, the number of sides of the radiation region increases and the power is dispersed. For that reason, when the ends are not aligned, power flowing in the longer side direction is reduced as compared with the case where the ends are aligned. As described above, since the radiation region radiates the radio wave having the resonance frequency determined by the length of the longer side, the greater the power flowing in the longer side direction, the higher the gain can be obtained. For that reason, desirably, the ends are aligned rather than the ends are not aligned.

A distance between the radiation regions parallel to each other in the longer side direction is desirably within several mm. When the distance is within several mm, the same power flows through each radiation element, and the resonance frequency corresponding to each radiation region can be obtained at the same time. Therefore, a wider frequency band is supported by the wireless tag communication device **201**.

One end of the longer side of the third radiation region **721** and one end of the longer side of the fourth radiation region **722** do not necessarily need to be aligned as illustrated in FIG. **8**. That is, one end of the longer side of the third radiation region **721** and one end of the longer side of the fourth radiation region **722** may have a positional relationship as illustrated in FIG. **7**. The same applies to the second type additional region **723**. That is, one end of the longer side of the third radiation region **721** and one end of the longer side of the second type additional region **723** do not necessarily need to be aligned, and one end of the longer side of the fourth radiation region **722** and one end of the longer side of the second type additional region **723** do not necessarily need to be aligned. When a plurality of second type additional regions exist, one end of the longer side of one second type additional region and one ends of the longer sides of other second type additional regions do not necessarily need to be aligned. However, when the ends are aligned, the effect that the gain is higher is obtained. When the ends are not aligned, the number of sides of the radiation region increases and the power is dispersed. For that reason, when the ends are not aligned, power flowing in the longer side direction is reduced as compared with the case where the ends are aligned. As described above, since the radiation region radiates the radio wave having the resonance frequency determined by the length of the longer side, the greater the power flowing in the longer side direction, the higher the gain can be obtained. For that reason, desirably, the ends are aligned rather than the ends are not aligned.

The third length may be substantially the same as or different from either the first length or the second length. The fourth length may be substantially the same as or different from one which is either the first length or the second length and is not substantially the same as the third length. The first length means the length of the longer side of the first radiation region **711**. The second length means the length of the longer side of the second radiation region **712**. The third length means the length of the longer side of the third radiation region **721**. The fourth length means the length of the longer side of the fourth radiation region **722**.

The direction of the longer side of the radiation region does not necessarily need to be perpendicular or parallel to the sheet conveyance direction. The direction of the longer side of the radiation region may be perpendicular or parallel to a direction (hereinafter referred to as "reference direction") forming a predetermined angle with the sheet conveyance direction. For example, the X-axis direction in FIGS. **7** and **8** may be perpendicular to the reference direction, and the Y-axis direction in FIGS. **7** and **8** may be parallel to the reference direction.

Whether the wireless tag communication device **201** exchanges information with the wireless tag using the power-feeding lines **641** or **642** may be determined in advance by a user or may be determined by the wireless tag communication device **201** by executing a predetermined process. When the user makes such a determines in advance, for example, the user specifies one of the power-feeding lines **641** or **642**, that radiates the polarized wave whose polarization plane is parallel to the direction of the wireless tag on the sheet to be processed, for information exchange.

When the wireless tag communication device **201** makes the determination, the following predetermined process is performed. For example, first, under the control of the wireless tag communication controller **501**, the power-feeding lines **641**, **642** to which the voltage is applied are switched at a predetermined cycle before exchanging information with the wireless tag. Then, each time the power-feeding lines **641**, **642** are switched, radiation of the radio wave and intensity of a reflected wave by the wireless tag of the radio wave are measured. The wireless tag communication controller **501** determines the switching timing. The reflected wave is a radio wave radiated by the wireless tag. The wireless tag communication controller **501** measures the reflected wave. The wireless tag communication controller **501** ends the switching process at the timing when the reflected wave having predetermined intensity or higher is observed. The wireless tag communication controller **501** determines one of the power-feeding lines **641**, **642**, which was the target of voltage application at the time when the switching was completed, as the one to be used for exchanging information with the wireless tag.

The functions of the image forming apparatus **10** and/or the wireless tag communication controller **501** described above may be realized by a computer. In such a case, the functions may be implemented by a program(s) stored in a computer-readable recording medium, copied from the recording medium to a computer system, and executed by a processor or controller. A "computer system" as used herein includes an operating system (OS) and hardware such as peripheral devices. A "computer-readable recording medium" refers to a storage medium or device such as a portable medium such as a flexible disk, a magneto-optical disk, a ROM, or a CD-ROM, a hard disk built in the computer system, and the like. The "computer-readable recording medium" may be cloud-based system, a server, or client, and/or accessible via a communication line such as a network or the Internet or the like. . A program as-described above may be a program for performing only some parts of the functions described above, and some or all the functions may be performed in conjunction with a program already recorded in the computer system.

According to at least one embodiment described above, the risk that information cannot be exchanged with a wireless tag due to tag type incompatibilities, differences, or the like can be reduced by use of a wireless tag communication device corresponding to the wireless tag communication device **201**.

While certain embodiments have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel embodiments described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the embodiments described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. A wireless tag communication device, comprising:

an antenna with a plurality of radiation regions through from which a polarized radio wave is emitted and including:

a first radiation region extending along a first direction crossing a conveyance direction of a wireless tag that is conveyed by a conveyance mechanism and having a first length in the first direction,

a second radiation region extending parallel to the first radiation region along the first direction and having a second length that is different from the first length in the first direction,

a third radiation region extending along the conveyance direction and having a third length in the conveyance direction, and

a fourth radiation region extending parallel to the third radiation region along the conveyance direction and having a fourth length that is different from the third length in the conveyance direction; and

a controller configured to cause at least one of the first, second, third, or fourth radiation regions to emit a polarized wave towards the wireless tag, wherein

each of the first and second radiation regions partially overlaps both the third radiation region and the fourth radiation region in a direction along which the polarized wave is emitted.

2. The wireless tag communication device according to claim **1**, wherein each of the plurality of radiation regions has a rectangular shape.

3. The wireless tag communication device according to claim **1**, wherein the plurality of radiation regions further include a fifth radiation region extending along the first direction and having a fifth length that is different from the first and second lengths in the first direction.

4. The wireless tag communication device according to claim 3, wherein the fifth radiation region partially overlaps both the third radiation region and the fourth radiation region.

5. The wireless tag communication device according to claim 3, wherein the plurality of radiation regions further include a sixth radiation region extending along the conveyance direction and having a sixth length that is different from the third and fourth lengths in the conveyance direction.

6. The wireless tag communication device according to claim 5, wherein the sixth radiation region partially overlaps each of the first, second, and fifth radiation regions in the direction along which the polarized wave is emitted.

7. The wireless tag communication device according to claim 1, wherein one side of each of the first and second radiation regions is aligned along the conveyance direction.

8. The wireless tag communication device according to claim 7, wherein one side of each of the third and fourth radiation regions is aligned along the first direction.

9. The wireless tag communication device according to claim 1, wherein

the antenna further includes a first contact through which power is supplied, and

the first contact is disposed on a portion of one of the plurality of radiation regions that overlaps another one of the plurality of radiation regions.

10. The wireless tag communication device according to claim 9, wherein

the antenna further includes a second contact through which power is supplied, and

the second contact is disposed on a portion of different one of the plurality of radiation regions from the one of the plurality of radiation regions on which the first contact is disposed.

11. A sheet processing apparatus, comprising:

a sheet conveyance path configured to convey a sheet having a wireless tag; and

a wireless tag communication device configured to communicate with the wireless tag and including:

an antenna with a plurality of radiation regions from which a polarized radio wave is emitted and including:

a first radiation region extending along a first direction perpendicular to a conveyance direction of the wireless tag along the conveyance path and having a first length in the first direction,

a second radiation region extending parallel to the first radiation region along the first direction and having a second length that is different from the first length in the first direction,

a third radiation region extending along the conveyance direction and having a third length in the conveyance direction, and

a fourth radiation region extending parallel to the third radiation region along the conveyance direction and having a fourth length that is different from the third length in the conveyance direction, and

a controller configured to cause at least one of the first, second, third and, fourth radiation regions to emit a polarized wave toward the wireless tag, wherein

each of the first and second radiation regions partially overlaps both the third radiation region and the fourth radiation region in a direction along which the polarized wave is emitted.

12. The sheet processing apparatus according to claim 11, wherein each of the plurality of radiation regions has a rectangular shape.

13. The sheet processing apparatus according to claim 11, wherein the plurality of radiation regions further include a fifth radiation region extending along the first direction and having a fifth length that is different from the first and second lengths in the first direction.

14. The sheet processing apparatus according to claim 13, wherein the fifth radiation region partially overlaps both the third radiation and the fourth radiation region.

15. The sheet processing apparatus according to claim 13, wherein the plurality of radiation regions further include a sixth radiation region extending along the conveyance direction and having a sixth length that is different from the third and fourth lengths in the conveyance direction.

16. The sheet processing apparatus according to claim 15, wherein the sixth radiation region partially overlaps each of the first, second, and fifth radiation regions in the direction along which the polarized wave is emitted.

17. The sheet processing apparatus according to claim 11, wherein one side of each of the first and second radiation regions is aligned along the conveyance direction.

18. The sheet processing apparatus according to claim 17, wherein one side of each of the third and fourth radiation regions is aligned along the first direction.

19. The sheet processing apparatus according to claim 11, wherein

the antenna further includes a first contact through which power is supplied, and

the first contact is disposed on a portion of one of the plurality of radiation regions that overlaps another one of the plurality of radiation regions.

20. An antenna for a wireless tag communicating device configured to communicate with a wireless tag conveyed by a conveyance mechanism, the antenna comprising:

a plurality of radiation regions from which a polarized radio wave is emitted, the plurality of radiation regions including:

a first radiation region extending along a first direction perpendicular to a conveyance direction of the wireless tag and having a first length in the first direction,

a second radiation region extending parallel to the first radiation region along the first direction and having a second length that is different from the first length in the first direction,

a third radiation region extending along the conveyance direction and having a third length in the conveyance direction, and

a fourth radiation region extending parallel to the third radiation region along the conveyance direction and having a fourth length that is different from the third length in the conveyance direction, wherein

each of the first and second radiation regions partially overlaps both the third radiation region and the fourth radiation region in a direction along which the polarized wave is emitted.

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